A Study of the Effects of Mounting Supports, and Dissipation on a Piezoelectric Quartz Double-Ended Tuning Fork Gyroscope

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Abstract

The quartz double-ended tuning fork gyroscope as shown in Figure 1, Ref. [1], was studied using COMSOL. The gyroscope has two detection modes; the first mode detects the angular velocity about a Z-axis perpendicular to the tuning fork plane (X-Y plane), while the second mode detects the angular velocity about a Y-axis that is the longitudinal axis along the length of the tuning fork. The mode shapes of the driving mode, Z-axis detection mode, and Y-axis detection mode are shown in Figure 2. Since the two detection modes do not vibrate symmetrically about the axes of symmetry of the double-ended tuning fork, they tend to interact more strongly with the tuning fork base and consequently with the mounting supports which include the spacers and silicon rubber adhesive used to bond the gyroscope to its substrate. There is dissipation of energy to the base substrate. The spacers and silicon rubber adhesive are the mounting supports that separate the vibrating tuning fork from a base substrate. The gyroscope characteristics were studied with respect to the thickness of the quartz plate and the silicon rubber adhesive height. It is important that the frequency of the driving mode be matched to the detection modes. A frequency spectrum of the Z-axis detection mode and the driving mode as a function of the gyroscope thickness is shown in Figure 3. From Figure 3, we observe that a gyroscope thickness of about 3 mm provides good frequency matching between the driving mode and the Z-axis detection mode. The sensitivity of the gyroscope to angular velocity was found to be dependent on both the silicon rubber adhesive thickness and quartz plate thickness. The thickness of the silicon rubber adhesive was found to be useful for fine tuning the frequency of the Z-axis detection mode to match the frequency of the driving mode. For example, Figure 4 shows the gyroscopic sensitivity for angular velocity about the Z-axis as a function of the thickness of the silicon rubber adhesive. Optimal tuning fork geometry, and silicon rubber adhesive could be found for maximizing the sensitivity of the gyroscope.

Reference

1. Kenji Sato, Atsushi Ono, and Yoshiro Tomikawa, "Experimental Study of Gyro Sensor Using Double-Ended Tuning Fork Quartz Resonator", Japanese Journal of Applied Physics, Vo. 43, No. 5B, 2004, pp. 3000-3003.

Figures used in the abstract

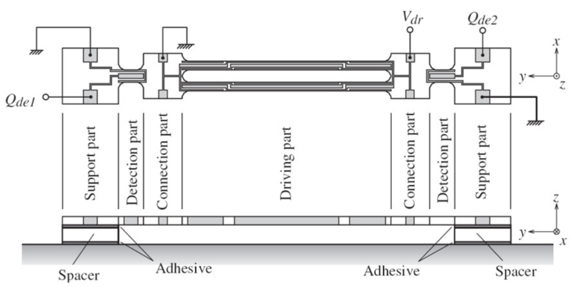


Figure 1: Structure of the quartz double-ended tuning fork gyroscope, Ref. [1].

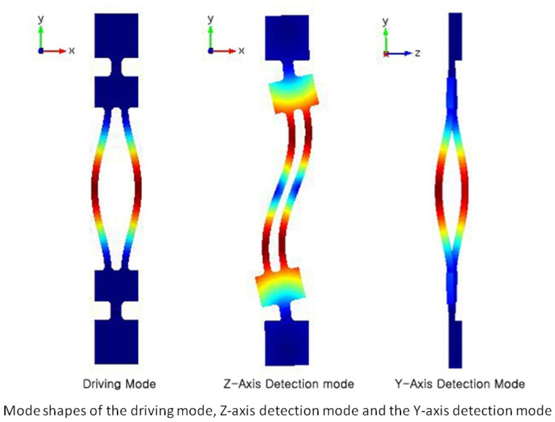
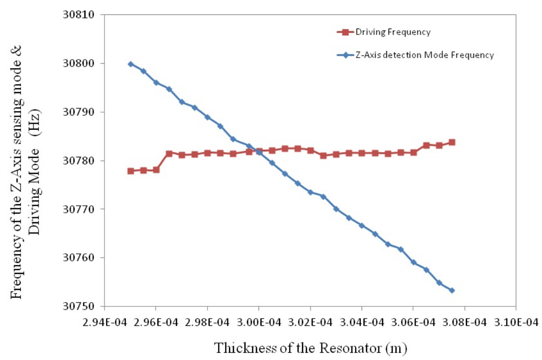
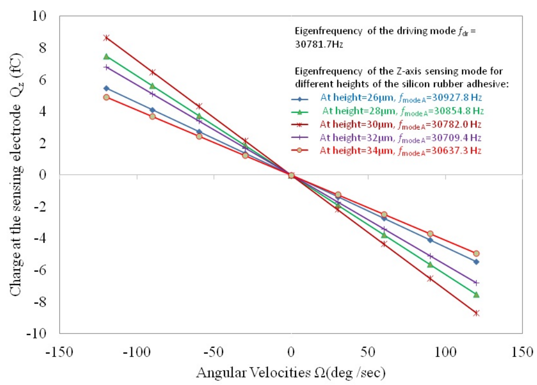


Figure 2: Mode shapes of the driving mode, Z-axis detection mode, and Y-axis detection mode.



Eigenfrequency of the resonator as function of thickness of the gyroscope sensor.

Figure 3: Resonant frequencies of the driving mode and Z-axis detection mode as a function of the quartz plate thickness.



Sensitivity of the gyroscope to Z-axis angular velocity Ω for different heights of silicon rubber adhesive

Figure 4: Sensitivity of the gyroscope to angular velocity about the Z-axis as a function of the thickness of the silicon adhesive.